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(54) **Telephone line circuit**

(57) A telephone line circuit includes balanced tip and ring leads for connection to a telephone set and an unbalanced line output lead. A first differential amplifier 10 has its input terminals connected through individual equal-valued resistors 1, 2 to the tip and ring leads, the values of each resistor being at least 10 times the off hook impedance of the telephone set. A second differential amplifier 16 has its input connected in a circuit path to a line input lead for receiving incoming signals, and its output connected in a circuit path to one of the tip or ring leads, and connected by a further resistor 32 to the input of the first differential amplifier which is connected to the other of the tip or ring leads. The value of the further resistor is selected to apply sufficient output signal from the second differential amplifier to the other input of the first differential amplifier so as to substantially cancel signals within the first differential amplifier appearing at its input terminals which were applied from the output of the second differential amplifier to the tip and ring leads.

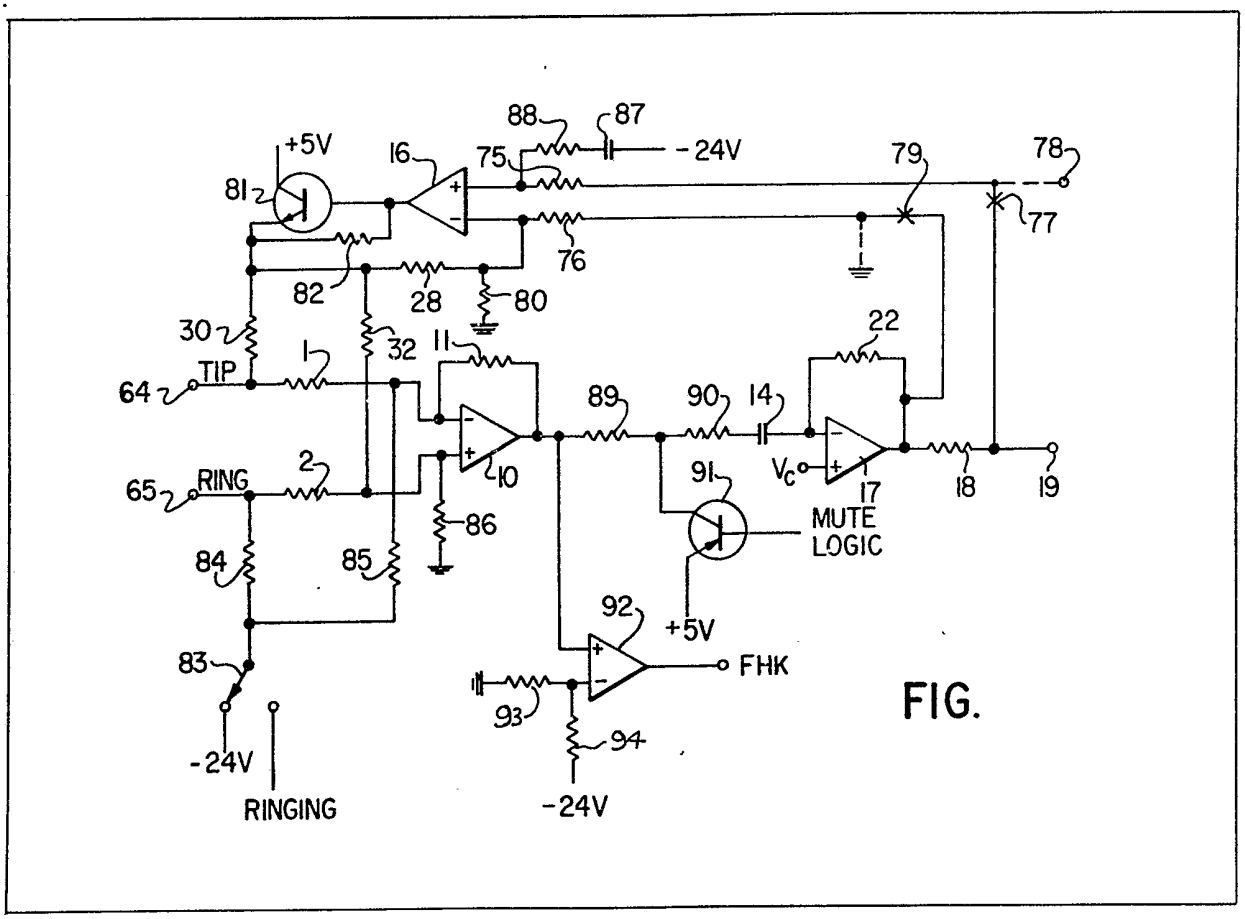

FIG.

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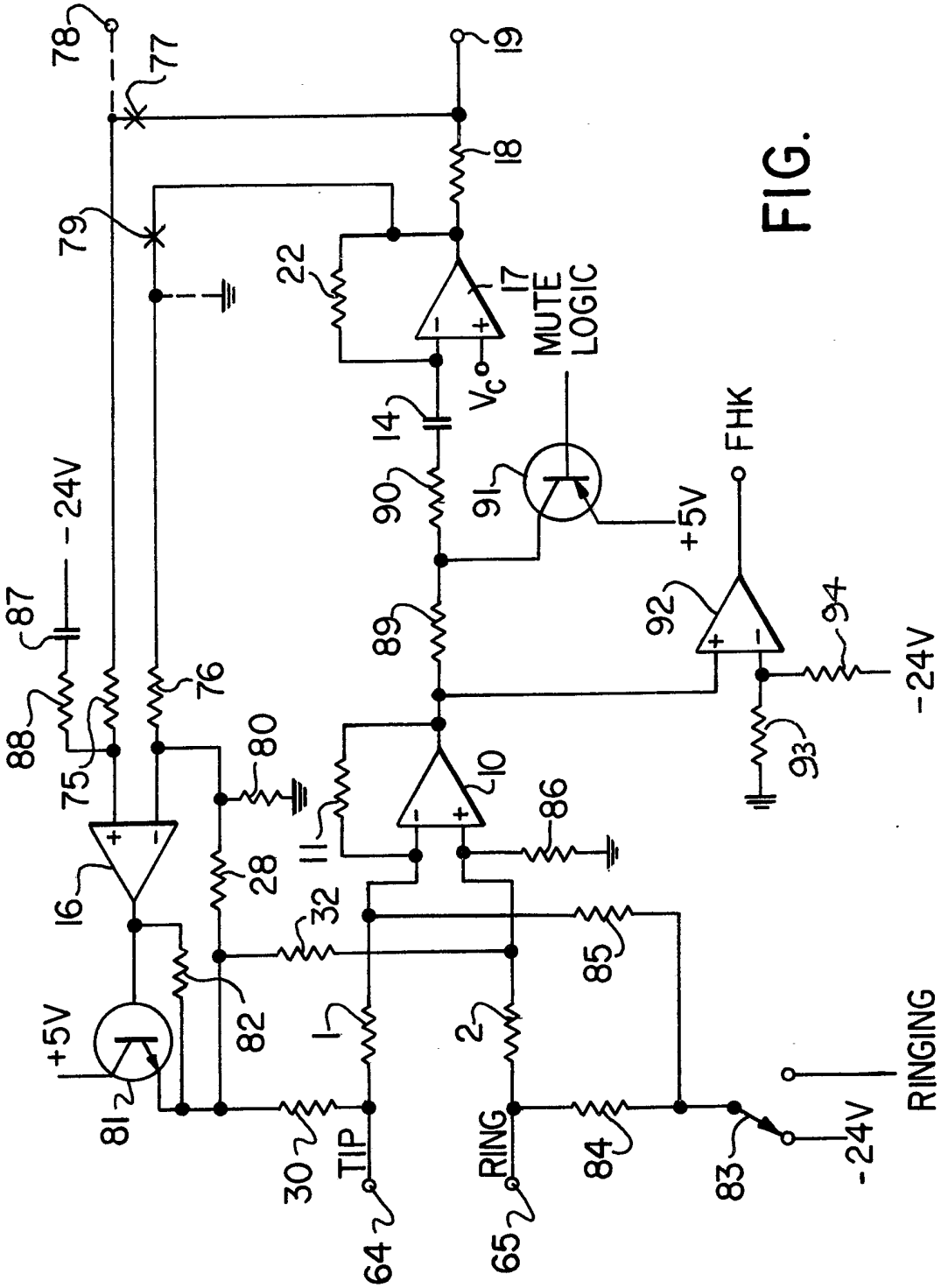
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FIG.

SPECIFICATION

Telephone line circuit

This invention relates to a transformerless bidirectional 4 wire/2 wire line circuit which is usefully employed in a PBX.

Line circuits which are used, for example in a PBX provide a facility for feeding direct current via a subscriber's line to the local telephone sets to which they are connected, and as well are required to block common mode signals while transmitting voice frequency signals in both directions. Common mode signals often arise as a result of the subscriber's lines passing close to a source of interference, such as house or building wiring which carries 60 Hz mains current. The voice frequency signals which are otherwise carried by the telephone lines are often found deeply modulated by the interfering common mode signals. Slight imbalance between the tip and ring leads of a long line would thus result in the common mode signal frequencies being differentially received. It is therefore important to stop the transmission of common mode signals within the line circuit.

Common mode signals are usually stopped by the use of a transformer in the line circuit. The tip and ring leads are connected to carefully balanced opposingly wound windings, which cancel the common mode signals. Since voice signals to be transmitted are differential in nature with respect to the tip and ring leads, these signals do not cancel and as a result are induced in the secondary winding and are applied to further switching or other circuitry.

However, since direct current must be fed to the local subscriber's telephone set, it is normally passed through the windings of the line circuit transformer. This direct current tends to saturate the transformer, requiring a relatively heavy core which does not saturate at normal line currents.

It is also highly desirable to apply ringing current to the local subscriber's line from the line circuit, and to be able to sense the state of the subscriber's telephone set should the telephone set go off hook.

For use particularly with an electronic PBX which is connected to a 4 wire unbalanced line, that is, with one pair connected to an input and another pair connected to an output of, for example, a Codec (coder-decoder), it is necessary to convert the balanced subscriber's line into a pair of unbalanced lines easily for application to the Codec, while at the same time raising the amplitude of a received signal from the Codec to a level required by the local subscribers telephone set.

The invention described in U.S. Patent 4,007,335 dated February 8, 1977, assigned to Bell Telephone Laboratories, utilizes an integrated circuit which is connected between the tip and ring leads and is intended to reduce common mode signals. This circuit exhibits a high impedance to differential voice signals appearing on the tip and ring leads, and exhibits a low impedance between the tip and ring leads and ground for common mode interference signals. While the described circuit would operate satisfactorily for the application to which it is intended, by its nature it cannot transform a balanced line to an unbalanced line (which otherwise would be done by a transformer circuit). Accordingly, it cannot be used to switch to an unbalanced line, or to a Codec, unless a following transformer is added.

Further, there is no facility for sensing the direct current level in the subscriber's line for determining the on or off hook status thereof. There is further no facility for changing the signal level applied to the Codec. Neither is there facility for applying ringing current to the subscriber's line nor for cutting it off when the subscriber has gone off hook.

In our patent application 48666/78 dated December 15, 1978, a circuit is described which converts a bidirectional balanced line to a bidirectional unbalanced line. A circuit has now been invented which converts the bidirectional balanced line to two unidirection unbalanced lines, one for receiving and one for outputting signals. Accordingly it can be used to feed a Codec directly without requiring an additional transformer. The bidirectional amplifier performs without introducing positive feedback or undesired sidetone. At the same time the circuit substantially blocks common mode signals which may appear on the balanced pair from being transferred to the unbalanced output line, and blocks signals from the unbalanced input from being transferred to the unbalanced output while being applied to the balanced line.

The circuit provides means for detecting the on or off hook status of the subscriber's line, for applying ringing to the subscriber's line, and for causing ringing to be cut off upon the local subscriber's telephone set going off hook.

It has been further found that the circuit can be considerably simplified from the invention in the above-noted patent application, and a novel circuit technique has been used to cancel any power supply hum which may appear on the tip and ring leads. It is therefore highly useful for an inexpensive PBX product.

In general, the invention is a telephone line circuit comprising a balanced tip and ring lead for connection to a telephone set, and an unbalanced line output lead, a first differential amplifier circuit means having input terminals connected through individual equal valued resistors to the tip and ring leads, the values of each of the resistors being at least 10 times the off hook impedance of the telephone set, the output of the first differential amplifier circuit being connected in a circuit path to a line output lead, for applying outgoing signals thereto, a second amplifier circuit having its input connected in a circuit path to a line input lead for receiving incoming signals, the output of the second amplifier circuit being connected in a circuit path to one of the tip or ring leads, the output of the second amplifier circuit also being

connected by a further resistor to the input of the first differential amplifier circuit which is connected to the other of the tip or ring leads, the value of the further resistor being selected to apply sufficient output signal from the second amplifier circuit to said other input of the first differential amplifier circuit as as to substantially cancel signals within the first differential amplifier circuit appearing at its input terminals which were applied from the output of the second differential amplifier circuit to the tip and ring leads.

In another embodiment the invention also further includes a circuit means for applying current from a D.C. power source via a capacitor in series with a resistor to the input of the second differential amplifier circuit, whereby A.C. ripple generated by the power source is applied to the tip and ring leads so as to cancel hum of similar frequency as said ripple carried by the leads.

A better understanding of the invention will be obtained by reference to the detailed description below, and to the following drawing, in which the Figure is a schematic of the invention.

The balanced tip and ring leads connected to terminals 64 and 65, for connection to a telephone set are connected through resistors 1 and 2 to the respective input terminals of differential operational amplifier 10. The operational amplifier has a feedback resistor 11 connected between its output and its inverting input in the conventional manner. Resistors 1 and 2 should each be at least 10 times the impedance of the off-hook telephone set which is to be connected to the tip and ring leads (although it could in some circumstances and special designs, be less, but should be large relative to said impedance). Resistor 86 connects the noninverting input terminal of operational amplifier 10 to ground. Resistor 11 is a feedback resistor around operational amplifier 10.

Using the principles of the invention described in the aforenoted patent application, the two inputs to a second differential amplifier 16 would be connected via respective resistors 75 and 76, one in bidirectional unbalanced line input/output terminal 19, and the other to the output of differential amplifier 17. The inverting input of operational amplifier 16 is also connected through resistor 80 to ground.

However, according to the present invention, for connection to a Coder-decoder (Codec) or other such 4 wire apparatus, the conductive path to terminal 19 is broken at point 77 and resistor 75 is connected instead to input terminals 78. The conductive path to the output of differential amplifier 17 is broken at point 79 and resistor 76 is connected instead to ground; both of the alternative connections are shown in dashed line. In this case amplifier 16 need not be of differential type.

Rather than utilizing a pair of transistors in the output circuit of differential amplifier 16, as in the afornoted invention, a single transistor 81 is used in the present invention. This allows connection of the collector of transistor 81 to a simplified power supply, e.g. to a +5 volt source, rather than to a split voltage power supply as in the aforenoted invention. The emitter is connected through resistor 30 to the tip lead and through resistor 32 to the noninverting input of differential amplifier 10. Resistor 82 is connected between the base and the emitter of transistor 81. Feedback resistor 28 is connected between the inverting input of operational amplifier 16 and the emitter of transistor 81.

The emitter of transistor 81 is connected through resistor 30 to the tip lead, and through resistor 32 to the noninverting input of differential amplifier 10.

In contrast to the aforenoted invention, the circuit is particularly useful for operation with PBXs utilizing a lower line voltage (e.g. —24 volts) than is normally used by a central office, which has the availability of a —48 volt supply. The present circuit is also adapted to use power supplies having A.C. filtering which is somewhat poorer than might otherwise be desired, as would be economically advantageous in a low-cost PBX.

Since the low cost power supply would often contain significant amounts of A.C. ripple, the power supply leads are applied to the tip and ring leads in a manner similar to the signals received from differential amplifier 16. The —24 volt supply is connected (optionally through switch 83, which switch is also connected to a source of ringing current) to the ring lead through resistor 84 and to the inverting input of differential amplifier 10 through resistor 85. The resistance of resistor 84 should be the same as that of resistor 30, e.g., one half the line resistance (or about 300 ohms) and resistor 85 should be of similar resistance as resistor 32 (e.g., about 200,000 ohms). Resistor 86 is connected from the noninverting input of differential amplifier 10 to ground, and can be, e.g., about 10,000 ohms.

It may be seen that with the above noted difference in resistance between resistors 84 and 85, the major portion of D.C. and A.C. ripple current from the —24 volt supply passes through resistor 84 to the ring lead. The current is applied with substantially reduced amplitude to the inverting input of differential amplifier 10. The effect of the reduced current being applied to the inverting input, and the high current being applied (with reduced ampltiude due to resistor 2) to the noninverting input causes cancellation of the A.C. ripple within the differential amplifier, and no significant ripple appears at the output of differential amplifier 10 which could be passed to output terminal 19.

A.C. ripple which appears between the tip and ring terminals 64 and 65 is cancelled by the application of the —24 volt supply through capacitor 87 series with resistor 88 to the noninverting input of differnetial amplifier 16, which blocks the —24 volt D.C. but applies the A.C. ripple to the differential amplifier. The values of capacitor 87 and resistor 88 should be adjusted so that there is unity gain in the tip lead, or more precisely so that the applied A.C. ripple cancels

whatever ripple appears between the tip and the ring leads.

In the present line circuit in which no conferencing function is required, the output of differential amplifier 10 can be connected through capacitor 14 to the input of differential amplifier 17. However, to facilitate remote muting of the outgoing signal, a pair of resistors 89 and 90 are connected in series with the output circuit of differential amplifier 10. The junction of resistors 89 and 90 are connected to the collector of a transistor 91, which has its emitter connected to the +5 volt supply. A lead from a muting logic circuit, not part of this invention, is connected to the base of transistor 91.

Upon the muting logic circuit applying a low level signal to the base of transistor 91, the +5 volt supply is connected through the emitter-collector circuit of transistor 91 to the junction of resistors 89 and 90. This effectively shunts the output of differential amplifier 10 to the supply, cutting off the transmission of signal to the input of differential amplifier 17.

An indication of an off-hook condition on the tip and ring leads can be obtained by connecting an operational amplifier 92 to one input of differential amplifier 10. The other input is connected to a voltage divider comprising resistors 93 and 94 connected between the —24 volt power supply lead and ground. With a change in the D.C. voltage across the tip and ring leads, the output voltage level of differential amplifier 10 changes, causing operational amplifier 92 to conduct once the threshold set by the voltage divider has been exceeded. The output lead OFHK of operational amplifier 92 provides an output signal which is indicative of the on or off-hook condition of the tip and ring leads.

The present circuit thus provides a considerably reduced cost transformerless line circuit which can be used with a reduced voltage and single ended power supply having less than optimum filtering, and which interfaces with a 4 wire circuit having unbalanced separate input-output ports, as would be required to connect to a Codec.

CLAIMS

1. A telephone line circuit comprising:

(a) a balanced tip and ring lead for connection to a telephone set, and an unbalanced line output lead,

(b) first differential amplifier means having its input terminals connected through individual equal valued resistor means to the tip and ring leads, the values of each of the resistor means being at least 10 times the off hook impedance of the telephone set,

(c) the output of the first differential amplifier means being connected in a circuit path to a line output lead, for applying outgoing signals thereto,

(d) second amplifier means having its input connected in a circuit path to a line input lead for receiving incoming signals,

(e) the output of the second amplifier means being connected in a circuit path to one of the tip or ring leads,

(f) the output of the second amplifier means also being connected by a further resistor means to the input of the first differential amplifier means which is connected to the other of the tip or ring leads,

(g) the value of the further resistor means being selected to apply sufficient output signal from the second amplifier means to said other input of the first differential amplifier means so as to substantially cancel signals within the first differential amplifier means appearing at its input terminals which were applied from the output of the second differential amplifier means to the tip and ring leads.

2. An amplifier circuit as defined in claim 2 further including means for applying current from a D.C. power source to said other of the tip or ring leads; and to the input of the first differential amplifier means which is connected to said one of the tip or ring leads though a resistor of similar value as said further resistor means, whereby A.C. ripple which may be carried by the power source current is applied to said other of the tip or ring leads and to the input of the differential amplifier means so as to substantially cancel within the first differential amplifier means.

3. A telephone line circuit comprising:

(a) a balanced tip and ring lead for connection to a telephone set, and an unbalanced line output lead,

(b) first differential amplifier means having its input terminals connected through individual equal valued resistor means to the tip and ring leads, the values of each of the resistor means being at least 10 times the off hook impedance of the telephone set,

(c) the output of the first differential amplifier means being connected in a circuit path to the line output lead, for applying outgoing signals thereto,

(d) second amplifier means having its input connected in a circuit path to the line output for receiving incoming signals,

(e) the output of the second differential amplifier means being connected to one of the tip or ring leads,

(f) the output of the second differential amplifier means also being connected by a further resistor means to the input of the first differential amplifier means which is connected to the other of the tip or ring leads,

(g) the value of the further resistor means being selected to apply sufficient output signal of the second differential amplifier means to said other input of the first differential amplifier means as to substantially cancel signals within the first differential amplifier means appearing at its input terminal from said one of the tip or ring lead from the output of the second differential amplifier means, and

(h) means for applying current from a D.C. power source to said other of the tip or ring leads; and to the input of the first differential amplifier means which is connected to said one of the tip or

ring leads through a resistor of similar value as said further resistor means, whereby A.C. ripple which may be carried by the power source current is applied to said other of the tip or ring leads and to the input of the differential amplifier means so as to substantially cancel within the first differential amplifier means.

4. An amplifier circuit as defined in claim 1, further including means for applying current from a D.C. power source via a capacitor in series with a resistor to the input of the second differential amplifier means, whereby A.C. ripple generated by the power source is applied to the tip and ring leads so as to cancel hum of similar frequency as said ripple carried by said leads.

5. A telephone line circuit comprising:

(a) a balanced tip and ring lead for connection to a telephone set, and an unbalanced line output lead,

(b) first differential amplifier means having its input terminals connected through individual equal valued resistor means to the tip and ring leads, the values of each of the resistor means being at least 10 times the off hook impedance of the telephone set,

(c) the output of the first differential amplifier means being connected in a ciruit path to line output lead, for applying outgoing signals thereto,

(d) second amplifier means having its input connected in a circuit path to the line output for receiving incoming signals,

(e) the output of the second differential amplifier means being connected to one of the tip or ring leads,

(f) the output of the second differential amplifier means also being connected by a further resistor means to the input of the first differential amplifier means which is connected to the other of the tip or ring leads,

(g) the value of the further resistor means being selected to apply sufficient output signal of the second differential amplifier means to said other input of the first differential amplifier means so as to substantially cancel signal within the first differential amplifier means appearing at its input terminal from said one of the tip or ring lead from the output of the second differential amplifier means, further including means for applying current from a D.C. power source via a capacitor in series with a resistor to the input of the second differential amplifier means, whereby A.C. ripple ripple generated by the power source is applied to said tip and ring leads so as to cancel hum of similar frequency as said ripple carried by said leads.

6. An amplifier circuit as defined in claim 1 further including means for applying current from a D.C. power source to said other of the tip or ring leads, and through a resistor of similar value as said further resistor means to the input of the first differential amplifier means which is connected to said one of the tip or ring leads, whereby an A.C. ripple current which may be carried by the power source current is applied to said one of the tip or ring leads and to the input of the differential amplifier means so as to substantially cancel within the first differential amplifier means, and means for applying current from said D.C. power source via a capacitor in series with a resistor to the input of the second differential amplifier means, whereby A.C. ripple current generated by the power source is applied to said tip and ring leads so as to cancel hum of similar frequency as said ripple carried by said leads.

7. A telephone line circuit comprising:

(a) a balanced tip and ring lead for connection to a telephone set, and an unbalanced line output lead,

(b) first differential amplifier means having its input terminals connected through individual equal valued resistor means to the tip and ring leads, the values of each of the resistor means being at least 10 times the off hook impedance of the telephone set,

(c) the output of the first differential amplifier means being connected in a circuit path to line output lead, for applying outgoing signals thereto,

(d) second amplifier means having its input connected in a circuit path to the line output for receiving incoming signals,

(e) the output of the second differential amplifier means being connected to one of the tip or ring leads,

(f) the output of the second differential amplifier means also being connected by a further resistor means to the input of the first differential amplifier means which is connected to the other of the tip or ring leads,

(g) the value of the further resistor means being selected to apply sufficient output signal of the second differential amplifier means to said other input of the first differential amplifier means as to substantially cancel signal within the first differential amplifier means appearing at its input terminal from said one of the tip or ring lead from the output of the second differential amplifier means, further including means for applying current from a D.C. power source to said other of the tip or ring leads, and through a resistor of similar value as said further resistor means to the input of the first differential amplifier means which is connected to said one of the tip or ring leads, whereby any A.C. ripple current which may be carried by the power source current is applied to said one of the tip or ring leads and to the input of the differential amplifier means so as to substantially cancel within the first differential amplifier means, and means for applying current from said D.C. power source via a capacitor in series with a resistor to the input of the second differential amplifier means, whereby A.C. ripple current generated by the power source is applied to said tip and ring leads so as to cancel hum of similar frequency as said ripple carried by said leads.

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